

# What do we do in Gerontechnology? Mapping the field through semantic consensus analysis (2017–2025)

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## Abstract

**Purpose:** This study presents a systematic analysis of research trends in papers published in the journal *Gerontechnology* from 2017 to 2025 using semantic consensus classification with multiple large language models.

**Methods:** A total of 183 papers were analyzed based on their titles and abstracts. Three large language models participated in an iterative semantic consensus classification process to assign papers to five technical solution categories and one general category. Papers in technical solution categories were further classified using the same semantic consensus classification process according to the Gerontechnology Matrix, which consists of five application domains and four main goals. Download statistics and author-provided keywords were analyzed to examine readership patterns and thematic evolution.

**Results:** General Issues constitutes the largest category, while the technical solution categories are represented in broadly comparable proportions. Matrix mapping shows that most technical solution papers are concentrated in the Health application domain, particularly associated with the goal of Prevention & Engagement, while other domains such as Housing, Communication, and Work & Leisure reflect distinct functional roles. Keyword analysis reveals sustained focus on aging, dementia, and assistive technologies, alongside increasing attention to accessibility, care contexts, interaction platforms such as smartphones and digital voice assistants, and emerging AI-based systems. The large number of unique keywords highlights substantial thematic diversity across published research.

**Conclusion:** AI-assisted semantic consensus classification using multiple large language models, combined with structured keyword analysis, provides a scalable, reproducible approach for examining research trends in journal publications and for ongoing monitoring of developments in gerontechnology.

Keywords: Gerontechnology; research trends; artificial intelligence; semantic consensus classification; large language models; keyword analysis

## INTRODUCTION

Gerontechnology is an interdisciplinary field that emerged in the early 1990s, integrating engineering, medicine, social sciences, and design to address the challenges and opportunities of an aging society. The International Society for Gerontechnology (ISG) defines it as “designing technology and environments for independent living and social participation of older persons in good health, comfort, and safety” (International Society for Gerontechnology, n.d.). As Bouma and colleagues noted, gerontechnology is characterized not by a single discipline but by its mission to align technological innovation with the needs and aspirations of aging populations (Bouma et al., 2007).

One of the most influential conceptual frameworks in the field is the Gerontechnology Matrix, which cross-tabulates five application domains: *Health, Housing, Mobility, Communication, and*

*Work & Leisure*, with four main goals: *Enrichment & Satisfaction, Prevention & Engagement, Compensation & Substitution, and Care Support & Care Organization*. The matrix was designed as a guide for designers and researchers to situate their work within a structured framework. Each cell represents a potential opportunity or need in gerontechnology, helping to align new designs and research initiatives with specific goals of supporting older adults in their daily lives (van Bronswijk et al., 2009).

To understand how the field continues to evolve, systematic analysis of the literature has become indispensable. Gerontechnology spans a wide range of technical, clinical, and social applications, making it challenging to maintain an integrated perspective. Structured literature analysis provides a means to map the field, identify imbalances and gaps across domains and goals, and inform researchers, practitioners, and policymakers in

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establishing priorities for future development. Research on aging and technology appears across a wide range of journals. Engineering and computer science journals emphasize technological development, while medical and nursing journals focus on clinical and caregiving applications. Social science journals often explore policy and psychosocial aspects. *Gerontechnology*, the official journal of the ISG, remains the only journal explicitly dedicated to this interdisciplinary field and thus provides an authoritative lens on its development. The 2017–2025 publication period provides a coherent and comprehensive dataset, offering an opportunity to examine structural and thematic patterns in research published in the journal.

## Semantic consensus analysis using large language models

Analyses of research literature have typically relied on manual coding, expert review, or bibliometric methods. Manual and expert-driven approaches involve direct interpretation of research content but are resource-intensive and difficult to scale to large numbers of papers. Bibliometric methods enable large-scale analysis based on citation relationships and publication patterns, but they do not directly capture the semantic meaning and intended focus of the research.

Recent advances in large language models (LLMs) enable literature analysis based on semantic interpretation. LLMs can interpret the purpose, conceptual focus, and application context of research described in natural language, enabling semantic classification of research papers based on their content (Li et al., 2024). However, outputs from individual models may vary due to differences in internal representations and reasoning processes (Dennstädt et al., 2024). To enhance robustness and reduce reliance on a single model's interpretation, consensus-based procedures can be used to align classifications across multiple models.

In this study, three LLMs (ChatGPT, Gemini, and DeepSeek) were used to perform semantic classification of all papers included in the analysis. Each model initially analyzed the titles and abstracts and generated category assignments with supporting justifications. These assignments were then refined through an iterative semantic consensus procedure, in which model outputs and rationales were compared and progressively aligned. This semantic consensus classification framework provides a transparent, reproducible, and scalable approach for organizing and analyzing published research.

## Objectives of this study

This study aims to characterize the evolution of gerontechnology research as reflected in papers published in the journal *Gerontechnology* from 2017 to 2025. To achieve this aim, the study applies semantic consensus classification and keyword analysis to:

- (1) Classify all papers published during this period into one General Issues category and five technical solution categories;
- (2) map the technical solution papers to the Gerontechnology Matrix across five application domains and four main goals;
- (3) examine the distribution of papers across categories, application domains, and main goals, and use average download counts as a comparative indicator of readership; and
- (4) analyze author-provided keywords to identify core and emerging research themes and their evolution over time.

This study makes both empirical and methodological contributions. Empirically, it provides a structured overview of research emphases, diversity, and temporal shifts within Gerontechnology. Methodologically, it demonstrates that semantic consensus classification using multiple LLMs provides a reproducible and scalable approach for organizing interdisciplinary research based on semantic interpretation of research content.

## SEMANTIC CONSENSUS CLASSIFICATION PROCEDURE

All papers published in the journal *Gerontechnology* between 2017 and 2025 were included in the analysis ( $n = 183$ ). Titles and abstracts served as the primary source for semantic consensus classification.

## Initial category structure

Gerontechnology research includes both technology-oriented studies and broader conceptual, methodological, and societal investigations. Most studies focus on the development, implementation, or evaluation of specific technological solutions designed to support older adults and caregivers and can be organized by their primary functional role. Based on long-term observation of gerontechnology research and publications, the following category titles, reflecting this functional perspective, were provided to the LLMs as the initial semantic structure:

- (1) Monitoring of vital signs and behavior patterns, and platforms for health management (Remote Monitoring)
- (2) Technology support for daily living of older adults and caregivers (Daily Living Support)
- (3) Platforms and technologies supporting social communication and participation (Social Participi-

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pation)

(4) Technology-based interventions for enhancing physical and cognitive abilities (Physical and Cognitive Enhancement)

(5) Robotics systems designed for senior care (Robotics for Care)

(6) General non-technical issues such as design methodology, policy, education, culture, and business (General Issues)

Categories (1) through (4) reflect functional roles of technological solutions. Robotics for Care was treated as a separate category because robotic systems often integrate multiple functional roles and represent an emerging technological area within gerontechnology. Category (6), General Issues, captures research addressing broader conceptual, methodological, or societal aspects of gerontechnology rather than a specific technological solution.

## Semantic consensus classification procedure

To enable reproducible and semantically consistent classification, we applied a semantic consensus classification procedure using multiple independent LLMs. In this study, three LLMs were used: ChatGPT, Gemini, and DeepSeek. Using multiple independent models reduces reliance on any single model's interpretation and improves robustness by enabling consensus-based classification grounded in independent semantic analysis.

The procedure consisted of iterative consensus rounds. Each LLM initially generated category assignments with supporting justifications. Papers were then assigned to three agreement levels: full consensus cases, where all models agreed on the same category; partial consensus cases, where two models agreed, and one disagreed; and non-consensus cases, where all models assigned different categories.

Following each round, classification justifications generated by all models across all papers were shared and reviewed to provide a common semantic context derived from the full dataset. Based on this shared context, each model refined its internal interpretation of the category structure and shared its updated interpretations before the next round of classification, allowing semantic definitions to evolve progressively across rounds. This round-level sharing ensured that semantic refinement was globally informed and not dependent on individual disagreements or processing order.

In subsequent rounds, only papers that had not yet reached full consensus were reclassified using each model's refined semantic interpretation.

However, the prior classifications and justifications of papers with full consensus remained part of the shared semantic context, ensuring that semantic refinement reflected the full distribution of the dataset rather than only ambiguous cases. This design maintained computational efficiency while preventing category definitions from overfitting to disputed papers.

This iterative process continued until semantic convergence was achieved, defined as full consensus in more than 95% of papers and elimination of all non-consensus cases. At this point, every paper had at least partial consensus, with agreement between at least two models. Final category assignments were determined based on majority agreement among the models. Final category definitions were proposed independently by each model based on the stabilized classification structure, and consensus definitions were established by majority vote among the models. The resulting category assignments and category definitions represent semantically stable classifications grounded in independent interpretation and iterative refinement. The procedure is summarized in Algorithm 1.

## Algorithm 1. Semantic consensus classification procedure

*Input:*

Paper set  $P = \{p_1, p_2, \dots, p_n\}$

Category set  $C = \{c_1, c_2, \dots, c_k\}$

LLM set  $M = \{m_1, m_2, m_3\}$

*Output:*

Final category assignment for each paper

Consensus category definitions

*Step 1. Initial classification*

For each model  $m$  in  $M$ :

    For each paper  $p$  in  $P$ :

        Assign category  $c \in C$

        Generate justification  $j$

Record all assignments and justifications.

*Step 2. Evaluate agreement*

For each paper  $p$  in  $P$ :

    If all models assign the same category  $\rightarrow$  mark as FULL\_CONSENSUS

    Else if two models agree  $\rightarrow$  mark as PARTIAL\_CONSENSUS

    Else  $\rightarrow$  mark as NON\_CONSENSUS

*Step 3. Iterative consensus refinement*

Repeat until convergence criteria are satisfied:

3.1 Share all classification assignments and justifications from all models across all papers

3.2 Refine and share category definitions based on shared semantic reasoning

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3.3 For each paper  $p$  marked PARTIAL\_CONSENSUS or NON\_CONSENSUS:

- For each model  $m$  in  $M$ :
- Reclassify paper using refined definitions
- Generate updated justification

3.4 Re-evaluate agreement status of all papers

## Step 4. Convergence criteria

Stop iteration when:

FULL\_CONSENSUS proportion > 95%

AND

NON\_CONSENSUS count = 0

## Step 5. Final assignment

For each paper  $p$  in  $P$ :

Assign final category based on majority agreement among models.

Return final assignments and consensus category definitions.

## RESULTS OF SEMANTIC CONSENSUS CLASSIFICATION

### Category classification results and consensus convergence

The semantic consensus classification procedure led to progressive convergence in category assignments across iterative rounds. As shown in *Table 1*, the proportion of full consensus cases increased from 74.3% in the initial round to 96.7% after the fifth round, while the number of non-consensus cases decreased to zero. At convergence, all papers reached at least partial consensus, enabling final category assignments to be determined by majority agreement among the models.

As shown in *Table 2*, research activity and readership varied considerably across categories. The overall average number of downloads per paper from the journal's website was 4,735 (recorded on February 10, 2026), which served as the reference value of 1.00 for calculating relative download ratios.

*General Issues* constituted the largest share of papers (35.5%) and recorded the highest average downloads (1.22 times the overall mean). In contrast, *Robotics for Care* accounted for only 8.2% of papers, although its average download count remained above the overall mean (1.09 times). The four technical solution categories—*Remote Monitoring*, *Daily Living Support*, *Social Participation*, and *Physical and Cognitive Enhancement*—showed broadly similar proportions of

papers. Among these, *Daily Living Support* exhibited the lowest relative download level (0.64 times the average), followed by *Social Participation* (0.75 times the average).

The consensus category definitions established through this process are provided in Appendix 1. These definitions represent operational classification criteria derived from the semantic consensus procedure and reflect how the LLMs interpreted and applied the categories in this study. They are intended solely to support the classification in this study and should not be interpreted as formal academic definitions of the technical solution categories.

### Mapping papers to the Gerontechnology Matrix

The same semantic consensus classification procedure described above was applied to map papers to the Gerontechnology Matrix. Only the 118 papers classified into technical solution categories (Categories 1–5) were included in this stage, as these papers represent specific technological solutions and are therefore appropriate for classification within the matrix framework.

For classification into application domains, the six technical categories used in the previous stage were replaced by the five Gerontechnology Matrix domains: *Health*, *Housing*, *Mobility*, *Communication*, and *Work & Leisure*. Each paper was analyzed by multiple LLMs based on its title and abstract, and semantic consensus classification was performed using the same iterative procedure and convergence criteria described earlier. The resulting distribution across application domains is presented in *Table 3*.

*Health* was the most represented application domain (60 papers, 50.8%), while *Mobility* and *Work & Leisure* were less represented (7 papers each, 5.9%). Average download counts were also calculated for each domain to provide a comparative indicator of readership. *Work & Leisure* showed the highest average downloads (8,829; ratio 1.86), whereas *Communication* showed the lowest average downloads (3,078; ratio 0.65).

The same procedure was subsequently applied to classify the 118 technical solution papers into the four main goals of the Gerontechnology Matrix: *Enrichment & Satisfaction*, *Prevention & Engagement*, *Compensation & Substitution*, and *Care Support & Care Organization*. In addition to the goal titles, the original explanatory descriptions provided by van Bronswijk et al. (2009) were supplied to the models to ensure consistent semantic interpretation. The resulting distribution across the main goals is presented in *Table 4*. Consensus

Table 1. Agreement levels among three LLMs across iterative rounds of semantic consensus classification (number of papers and percentage)

Round	Full agreement	Partial agreement	No agreement
0	136 (74.3%)	44	3
1	160 (87.4%)	20	3
2	170 (92.9%)	11	2
3	174 (95.1%)	8	1
4	175 (95.6%)	7	1
5	177 (96.7%)	6 (3.3%)	0

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Table 2. Distribution of papers across six categories and corresponding average download counts and relative download ratios

Category	No. papers	Avg. downloads
1. Remote monitoring	28 (15.3%)	4,913 (1.04)
2. Daily living support	28 (15.3%)	3,025 (0.64)
3. Social participation	26 (14.2%)	3,574 (0.75)
4. Physical & cognitive enhancement	21 (11.5%)	4,292 (0.91)
5. Robotics for care	15 (8.2%)	5,155 (1.09)
6. General issues	65 (35.5%)	5,916 (1.25)
Total	183	4,735 (1.00)

was reached in the third round for application domain mapping and in the fifth round for main goal mapping.

## MAPPING RESEARCH STRUCTURE AND ORIENTATION IN GERONTECHNOLOGY (2017–2025)

### Reliability and generalizability of semantic consensus classification

The high level of agreement achieved through the semantic consensus classification procedure demonstrates the reliability of using multiple LLMs to categorize gerontechnology research. Full agreement increased substantially across iterative rounds, reaching 96.7% at convergence, with no remaining cases of non-agreement (Table 1). This convergence indicates that independently generated semantic interpretations can stabilize through iterative refinement, producing consistent classification outcomes even in an interdisciplinary domain where category boundaries are not always clearly defined.

The same semantic consensus procedure was successfully applied to the classification of papers within the Gerontechnology Matrix domains and goals. Consensus was rapidly achieved in these independent mapping tasks, indicating that semantic consensus classification provides a stable, transferable method for organizing interdisciplinary literature based on semantic interpretation rather than predefined classification frameworks. This approach also addresses key limitations of traditional manual classification, which is often time-consuming and subject to individual interpretation.

Finally, the consensus-derived category definitions represent reproducible operational classification criteria. Because these definitions reflect shared semantic interpretations among independent models, they provide a transparent and consistent basis for future classification of gerontechnology research.

Table 3. Distribution of technical solution papers across five Gerontechnology Matrix application domains (number of papers)

Category	Health	Housing	Mobility	Communication	Work & leisure
1. Remote monitoring	24	4	0	0	0
2. Daily living support	9	15	2	1	1
3. Social participation	3	0	0	19	4
4. Physical & cognitive enhancement	15	0	5	0	1
5. Robotics for care	9	4	0	1	1
Total	60	23	7	21	7
Average downloads	3,497 (0.74)	4,787 (1.01)	5,080 (1.07)	3,078 (0.65)	8,829 (1.86)

## Distribution of research across General Issues and technical solution categories

The distribution of papers across *General Issues* and the five technical solution categories reveals the overall structural orientation of gerontechnology research during the study period. As shown in Table 2, *General Issues* accounted for the largest share of publications, 35.5% of all papers, and recorded the highest relative download level (1.25). This predominance, together with strong readership interest, reflects the interdisciplinary nature of gerontechnology, where conceptual discussions, reviews, and integrative perspectives play a central role in shaping the field and connecting diverse technological and application domains.

Overall, the relatively balanced distribution across the technical solution categories indicates that gerontechnology has developed along multiple technological directions rather than concentrating in a single dominant domain. Differences in relative download levels further suggest that research activity and readership attention are not uniformly aligned across categories.

Among the technical solution categories, Robotics for Care accounted for the smallest proportion of papers (8.2%) but recorded the second-highest relative download level (1.09). This pattern suggests that robotics, a more specialized and emerging segment within gerontechnology, attracts considerable attention. In contrast, Daily Living Support exhibited lower relative download levels (0.64) despite representing a substantial portion of the research output. This category partially overlaps with the more established field of assistive technology, which has dedicated publication venues and a longer research history, potentially influencing readership patterns within the gerontechnology journal.

Download statistics should be interpreted with caution. Earlier papers have had more time to accumulate downloads, and the counts reflect only those recorded on the Gerontechnology journal's open-access website. Additional access through databases or institutional repositories may introduce variation in the raw numbers. Nevertheless, when viewed in aggregate, relative download levels provide a useful comparative indicator of readership patterns across categories within the dataset.

## Mapping research distribution within the Gerontechnology Matrix

Mapping the technical solution papers onto the Gerontechnology Matrix reveals the distribution of gerontechnology research across application domains

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Table 4. Distribution of technical solution papers across Gerontechnology Matrix domains and goals (number of papers)

		Application domain				
		Health	Housing	Mobility	Communication	Work & leisure
Main goal	Enrichment & satisfaction	10	2	0	16	7
	Prevention & engagement	30	3	3	4	0
	Compensation & substitution	4	12	4	0	0
	Care support & care organization	16	6	0	1	0

and main goals. As shown in Table 3, the Health domain accounted for nearly half of all technical solution papers (50.8%), substantially exceeding Housing (19.5%), Communication (17.8%), Mobility (5.9%), and Work & Leisure (5.9%). This distribution indicates that technology solutions in gerontechnology are strongly concentrated in the Health domain. Health is the leading application domain for several technical solution categories, including Remote Monitoring, Physical and Cognitive Enhancement, and Robotics for Care. In contrast, Housing is the primary domain for Daily Living Support technologies, while Communication is the leading domain for Social Participation technologies. Mobility and Work & Leisure remain sparsely represented, with Mobility primarily associated with Physical and Cognitive Enhancement and Work & Leisure with Social Participation technologies.

When examined in relation to the matrix goals (Table 4), distinct functional associations emerge across domains. Technology solutions in the Health and Mobility domains are predominantly associated with the goal Compensation & Substitution. Solutions in the Housing domain are mainly associated with Compensation & Substitution, while those in the Communication and Work & Leisure domains are primarily associated with Enrichment & Satisfaction. Care Support & Care Organization is most strongly represented in the Health domain, with additional presence in Housing.

Taken together, the matrix mapping reveals an uneven distribution of research activity, with

dense concentrations in specific domain–goal regions and relatively sparse representation in others. This distribution highlights the structural balance of technology development across the Gerontechnology Matrix and provides a basis for identifying areas of concentration and underrepresentation within the current research landscape.

## KEYWORD ANALYSIS AND EMERGING RESEARCH THEMES

Author-provided keywords offer direct insight into the research topics, methodological approaches, and technological focus areas emphasized by individual studies. Analyzing keywords therefore provides a content-level perspective that complements category and matrix mapping by revealing dominant themes, emerging areas, and the conceptual structure of the field.

### Three-stage keyword normalization and semantic consolidation

We conducted a content-level analysis using the author-provided keywords from all 183 papers. In total, there were 882 keyword instances, comprising 612 unique keywords, of which 519 (84.8%) appeared only once. This high proportion of unique keywords reflects substantial diversity in terminology. However, many keywords differed in form while referring to similar or identical concepts. To address this issue and enable systematic thematic analysis, we applied a three-stage, AI-assisted keyword normalization and semantic consolidation procedure.

First, formal normalization was performed to standardize keyword forms. Abbreviations were expanded (e.g., AI to artificial intelligence, ICT to information communication technology, and IoT to internet of things), plural forms were converted to singular, spelling conventions were standardized, and punctuation differences were removed. This step ensured consistency in lexical representation.

Second, semantic synonym consolidation was conducted using an expert-defined source-to-

Table 5. Keyword clusters from 183 papers in Gerontechnology (2017–2025)

Cluster	Keywords (with counts)
Research focus & populations (≥ 4)	older adult (70); dementia (38); technology (38); aging (15); social connectedness (11); long term care (9); gerontechnology (8); care (7); long term care institution (7); physical activity (7); activity of daily living (6); caregiver (6); digital inclusion (6); mobility (6); aging in place (5); behavior (5); digital divide (5); fall (5); informal caregiver (5); learning (5); loneliness (5); mild cognitive impairment (5); quality of life (5); attitude (4); cognitive impairment (4); digital literacy (4); value (4)
Research designs & methodological approaches (≥ 3)	technology acceptance (20); intervention (9); usability (8); user experience (7); qualitative research (4); design (3); serious game (3); human factor (3); innovation (3); self management (3)
Technological solutions & systems (≥ 3)	assistive technology (13); robot (11); digital health (10); app (8); media (7); smartphone (7); tablet (7); digital voice assistant (6); computer (5); communication technology (4); exergame (4); sensor (4); artificial intelligence (3); assistive robot (3); smart home (3); social technology (3); virtual reality (3); wearable (3)

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Table 6. Keyword clusters from General Issue papers in Gerontechnology (2017–2025)

Cluster	Keywords (with counts)
Research focus & populations (≥ 3)	older adult (23); technology (18); dementia (13); aging (7); gerontechnology (7); digital divide (5); digital literacy (4); digital inclusion (3); attitude (3); long term care institution (3); age (3)
Research designs & methodological approaches (≥ 3)	technology acceptance (9)
Technological solutions & systems (≥ 3)	assistive technology (7); digital health (5); app (4); digital voice assistant (3); information communication technology (3); media (3)

canonical dictionary. Conceptually equivalent terms were merged based on meaning rather than form. For example, “elderly,” “older adults,” and related variants were consolidated into the canonical keyword “older adult,” while related terms referring to Alzheimer’s disease were consolidated under “dementia.” This process established a consistent conceptual vocabulary suitable for systematic analysis.

Third, an iterative refinement process ensured full coverage and internal consistency. Each keyword was reviewed against the dictionary, and unmapped or ambiguous terms were resolved using contextual interpretation and expert validation. The finalized source-to-canonical dictionary contained 633 source entries mapped to 388 unique canonical keywords, providing a transparent and reproducible semantic framework for keyword analysis.

After canonical conversion, the 183 papers contained 364 unique canonical keywords, of which 245 (67.3%) appeared only once. This reduction demonstrates the effectiveness of normalization and consolidation in revealing underlying conceptual patterns while preserving the diversity of research topics. The large proportion of unique keywords and low-frequency terms, even after consolidation, highlights the substantial heterogeneity of gerontechnology research. This diversity indicates that the field is characterized by multiple parallel research directions rather than convergence toward a small number of dominant technological themes.

Consolidated high-frequency thematic clusters As shown in Table 5, the canonical keywords were grouped into three thematic clusters, and only high-frequency keywords were reported after consolidation. This clustering reflects the fundamental structural components of scientific research, as author-provided keywords typically describe the target populations or problem con-

texts, the methodological approaches used, and the technological systems developed or applied.

*Research Focus & Populations* (≥ 4 occurrences) includes keywords related to target populations, health conditions, and functional or social issues addressed in the studies. *Research Designs & Methodological Approaches* (≥ 3 occurrences) includes keywords describing study designs, evaluation frameworks, and methodological approaches used to investigate gerontechnology applications. *Technological Solutions & Systems* (≥ 3 occurrences) includes keywords describing technological tools, devices, and digital systems developed or applied to address identified needs. This clustering highlights the dominant conceptual and technological themes within gerontechnology research while reducing fragmentation caused by synonymous or variant terminology.

Within *Research Focus & Populations*, the cluster is anchored by population descriptors such as *older adult* (70) and *aging* (15), as well as the field orientation reflected in *technology* (38) and *gerontechnology* (8). *Dementia* (38), along with *mild cognitive impairment* (5), highlights the central importance of cognitive health. Care contexts are represented by *long term care* (9), *long term care institution* (7), *care* (7), *caregiver* (6), and *informal caregiver* (5), while living environments are reflected in *aging in place* (5). Functional health appears through *physical activity* (7), *mobility* (6), *activity of daily living* (6), and *fall* (5). Psychosocial dimensions include *social connectedness* (11), *loneliness* (5), *behavior* (5), *attitude* (4), *learning* (5), *value* (4), and *quality of life* (5). Access and equity concerns are evident in *digital divide* (5), *digital inclusion* (6), and *digital literacy* (4).

Within *Research Designs & Methodological Approaches*, *technology acceptance* (20) is the most prominent methodological focus. Evaluation approaches such as *usability* (8) and *user experi-*

Table 7. Top keywords in Research Focus & Populations by time period

Period	Keywords (with counts)
2017–2019	dementia (14); social connectedness (5); physical activity (4); care (3); fall (3); long term care institution (3)
2020–2022	dementia (15); activity of daily living (6); long term care institution (4); mild cognitive impairment (4); quality of life (4); social connectedness (4); attitude (3); digital divide (3); digital inclusion (3); long term care (3)
2023–2025	dementia (9); long term care (4); mobility (4); informal caregiver (3); loneliness (3)

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Table 8. Top keywords in Technological Solutions & Systems by time period

Period	Keywords (with counts)
2017–2019	digital health (5); assistive technology (4); app (3); computer (3); robot (3); tablet (3)
2020–2022	media (6); assistive technology (5); robot (5); tablet (4); app (3); artificial intelligence (3); digital voice assistant (3)
2023–2025	assistive technology (4); smartphone (4); digital health (3); digital voice assistant (3); robot (3)

ence (7) are common, alongside *intervention* (9) studies. Additional methods, including *qualitative research* (4), *design* (3), *human factor* (3), *innovation* (3), *serious game* (3), and *self management* (3) reflect continued emphasis on user-centered development and behavioral engagement.

Within *Technological Solutions & Systems*, *assistive technology* (13), *robot* (11), and *digital health* (10) represent the dominant technological domains, reflecting the central role of health-related and assistive solutions in gerontechnology. Interaction platforms such as *smartphone* (7), *tablet* (7), *computer* (5), *digital voice assistant* (6), and *app* (8), along with *communication technology* (4) and *media* (7), support user interaction, accessibility, and connectivity. Additional solutions, including *exergame* (4), *sensor* (4), and *smart home* (3), extend technological support into everyday living environments. Emerging technologies such as *virtual reality* (3), *artificial intelligence* (3), *wearable* (3), *assistive robot* (3), and *social technology* (3) reflect ongoing diversification toward more intelligent, adaptive, and integrated gerontechnology systems.

## Conceptual focus distinctive to General Issues papers

*General Issues* papers represent the largest category and reflect the conceptual and integrative aspects of gerontechnology research. Their keyword structure was examined separately to identify themes that differ from technical solution papers. While keywords such as *older adult*, *dementia*, and *aging* are prominent across the entire gerontechnology literature (Table 5), *General Issues* papers are distinguished by their stronger emphasis on technology access and adoption. As shown in Table 6, keywords such as *digital divide* (5), *digital literacy* (4), *digital inclusion* (3), and *technology acceptance* (9) appear disproportionately in *General Issues* papers, highlighting a primary focus on barriers, accessibility, and user acceptance rather than technological implementation.

In addition, technology-related keywords in *General Issues* papers, such as *technology* (18), *assistive technology* (7), and *digital health* (5), primarily refer to technology in general terms rather than specific systems or devices. These patterns indicate that *General Issues* papers focus on the relationship between older adults and technology, particularly accessibility, adoption, and broader

technological contexts, rather than on the development of specific technological solutions.

## Temporal shifts in research focus and technology solutions

To examine how research focus evolved over time, ranked keyword lists were generated for three periods: 2017–2019, 2020–2022, and 2023–2025. General descriptors such as *older adult*, *technology*, *gerontechnology*, and *aging* were excluded to highlight more specific research themes.

Table 7 presents the top keywords in *Research Focus & Populations* by time period. Across all three periods, *dementia* remained the most consistently represented research focus, indicating sustained attention to cognitive decline in aging populations. During 2017–2019, research emphasized functional and health-related concerns, including *physical activity*, *fall*, and *long term care institution*, reflecting early focus on functional ability and institutional care contexts.

During 2020–2022, research themes broadened to include activity of daily living, mild cognitive impairment, and quality of life, indicating increased attention to functional independence and early-stage cognitive decline. Keywords such as *digital divide* and *digital inclusion* also emerged, reflecting growing recognition of technological accessibility as an important factor in gerontechnology.

By 2023–2025, research attention increasingly reflected broader care and social contexts, with keywords such as *long term care*, *informal caregiver*, *mobility*, and *loneliness* becoming more prominent. These shifts suggest a gradual expansion of gerontechnology research from primarily cognitive and functional concerns to broader care environments and the psychosocial aspects of aging.

Table 8 shows the top keywords in *Technological Solutions & Systems* by time period. Across all three periods, *assistive technology* remained one of the most consistent technological keywords, indicating its continuing role as a core applied domain in gerontechnology research. Other major technological areas, including *digital health* and *robot*, also appeared repeatedly, reflecting sustained interest in health-related and robotic solutions.

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Clear shifts are visible in interaction devices over time. In 2017–2019, interaction was primarily associated with traditional computing platforms, including computer, tablet, and app. During 2020–2022, media-based and intelligent interaction technologies became more prominent, with increased references to media, artificial intelligence, and digital voice assistant. In the most recent period (2023–2025), smartphone emerged as a leading interaction platform, while digital voice assistant and robot continued to appear among the top keywords.

Overall, the progression reflects the persistence of core assistive technologies alongside a gradual transition from traditional computing interfaces toward more mobile and adaptive interaction platforms.

## DISCUSSION AND CONCLUSIONS

This study provides a systematic mapping of research trends in papers published in the journal *Gerontechnology* from 2017 to 2025 using semantic consensus classification and keyword analysis supported by large language models. The results show that General Issues constitutes the largest share of papers, while the technical solution categories are otherwise distributed relatively evenly, with Robotics for Care representing a smaller proportion than the others. This distribution indicates that the journal publishes a substantial volume of conceptual and integrative work alongside technology-focused studies spanning multiple solution areas.

Keyword analysis provides additional insight into the thematic structure and evolution of published research. Frequently occurring keywords such as older adult, dementia, and aging reflect the central populations and health concerns addressed in gerontechnology. At the same time, the large number of unique and low-frequency keywords highlights the diversity of topics, indicating that research published in *Gerontechnology* spans multiple parallel directions rather than converging on a single dominant technological trajectory. Temporal analysis shows continued attention to cognitive and functional health, accompanied by increasing emphasis on care contexts, including activity of daily living, long-term care, and caregiving environments.

The analysis of General Issues papers highlights their distinct conceptual role. Unlike technical so-

lution papers, which focus on specific systems and devices, General Issues papers emphasize accessibility, adoption, and the broader relationship between technology and older adults. Keywords such as digital divide, digital literacy, digital inclusion, and technology acceptance appear disproportionately in this category, indicating sustained attention to barriers to technology use and equitable access. In contrast, technology-related keywords in these papers tend to refer to technology in general terms rather than specific implementations, reinforcing their integrative and conceptual focus.

Within Technological Solutions & Systems, assistive and monitoring technologies form a stable core across all time periods. Keywords such as assistive technology, digital health, and robot appear consistently, reflecting ongoing development in these established domains. Interaction technologies show gradual evolution, from earlier emphasis on computer, tablet, and app toward increased use of smartphone and digital voice assistant, indicating a shift toward more accessible and natural interaction modalities. The emergence of artificial intelligence in recent years further underscores the growing integration of intelligent data processing and adaptive capabilities within gerontechnology systems. These patterns suggest continuity in core technological approaches alongside incremental adoption of more intelligent, user-centered, and widely accessible platforms.

The semantic consensus classification approach used in this study provides a practical and reproducible method for organizing published research. The iterative consensus process produces stable and transparent classification outcomes, while the three-stage keyword normalization and consolidation procedure enables consistent identification of thematic structures across diverse terminology. Beyond conventional bibliometric indicators, this framework provides a structured approach for examining the conceptual and technological evolution reflected in the journal. This process has already been developed into a semi-automated framework capable of generating structured trend analyses of published papers, providing a practical tool for ongoing monitoring of research developments in Gerontechnology.

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## Appendix 1. Consensus definitions of the six technical categories

### 1. Monitoring of vital signs and behavior patterns; platforms for health management

Research in this category focuses on technologies and studies whose primary aim is measurement, detection, assessment, prediction, or management of health-related signals and behavior patterns — including physiological vital signs (e.g., heart rate, EDA, blood pressure, glucose), mobility and activity patterns, sleep/fall detection, affect or responsive behaviours — and the platforms, analytics (AI, Markov/HMM, NLP, facial/emotion recognition) and dashboards that aggregate those data for clinical or self-management use. It covers passive and active sensing modalities (wearables, in-home sensors, video, smartphones, mixed reality) and validation/usability work when the central contribution is about sensing performance, assessment accuracy, monitoring workflows or decision support. This category is distinct from Category 2 (assistive technologies for daily living and caregiver tasks) and Category 3 (social communication/engagement) when those works prioritize assistance or social participation rather than health monitoring; from Category 4 when the primary goal is intervention or training to improve ability rather than measurement; from Category 5 when robots are studied chiefly as caregivers or companions rather than monitoring platforms; and from Category 6 when the emphasis is on high-level design, policy or cultural issues rather than sensor/assessment outcomes — although usability and stakeholder studies overlap and are included here when tightly linked to monitoring functionality, implementation, or clinical validity.

### 2. Technology support for the daily lives of older adults and caregivers

Category 2 comprises research on technologies that directly support the day-to-day functioning, independence, safety and care coordination of older adults and their informal/formal caregivers — e.g., home-based reminder and prompting systems, voice-activated digital home assistants, smart-home/AAL platforms, medication dispensers, task lighting, biodynamic lighting, real-time location systems, modular smart furniture, calming screens, navigation aides, interactive calendars and caregiver coaching/communication tools. It is distinct from Category 1 (which focuses on continuous clinical monitoring, vital-signs, behavior-pattern analytics and health-management platforms), Category 3 (which centers on social communication and participation), and Category 4 (which targets interventions that train or rehabilitate physical/cognitive capacity rather than provide compensatory or environmental supports); robot-centered studies belong in Category 5 when the primary contribution is robotic systems and in Category 2 only when the emphasis is pragmatic, non-robotics research about daily-life support. Stud-

ies of usability, onboarding, device-learning, and field evaluations belong here when their aim is enabling everyday use or caregiving tasks, whereas work primarily about methodological evaluation, policy, digital-literacy theory, or instrument development should be classified under Category 6 (general issues) or moved to a different clinical/assessment category if measuring capacity rather than technology-supported daily functioning.”

### 3. Platforms for social communication and participation

This category covers research on digital platforms, apps, devices and user interfaces whose primary purpose is to enable social communication, community participation and meaningful engagement for older adults and their caregivers — including social networking, video calling, group or intergenerational activities, online support groups, digital storytelling, augmented-reality cultural tours, tangible social interfaces, smart-speaker engagement and platform-level evaluations of social outcomes. It is distinguished from monitoring or health-management systems (Category 1), assistive technologies for everyday tasks (Category 2), and interventions primarily designed to restore physical or cognitive function (Category 4) or embodied robotic care (Category 5) by focusing on social/relational outcomes (connectedness, participation, reminiscence, social capital) rather than physiological sensing, ADL support, or clinical rehabilitation. Many included studies examine design, usability, implementation and barriers when social engagement is the main objective; where work overlaps (e.g., a game yielding cognitive benefits or a device evaluated for both engagement and health monitoring), the deciding boundary is the study’s primary aim and measured outcomes — if social connection and participation are central, classify as Category 3, otherwise route to the more relevant category.”

### 4. Technology interventions for enhancing physical and cognitive abilities

Category 4 covers empirical and design research where a technology (hardware, software, sensor-driven device, wearable, game, VR/AR environment, lighting system, smartphone/tablet app, or rehabilitative assistive device) is developed, adapted, or tested with the explicit primary aim of improving or restoring physical and/or cognitive abilities (e.g., mobility, balance, strength, gait, memory, attention, executive function, engagement) in older adults or people with cognitive/functional impairments. It excludes studies whose main purpose is passive monitoring, clinical data management, care coordination or social communication (Category 1–3), purely robotic system design or deployment papers without an evaluated therapeutic/training aim (Category 5 unless the robot is used as an intervention to train abilities), and papers focused primarily on methodology, implementation/process evaluation, policy or education without efficacy/effectiveness outcomes (Category 6); conversely, process or feasibility work belongs here when it directly tests an intervention’s effects or usability for improving function. In cases of mixed or disputed labeling (e.g., app-based nutritional education, selection tools for apps, building-activity assessments, or process evaluations), classify as Category 4 when the technology is intended and evaluated as an in-

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intervention to change physical/cognitive outcomes or behavior, otherwise classify under implementation/methodology or other relevant categories.”

## *5. Robotics systems designed for senior care*

Category 5 covers empirical and design research about embodied robotic systems for older adults’ care — including social/companion robots, humanoids, teleoperated/telepresence robots, mobile manipulators and assistive platforms that deliver social interaction, screening (e.g., depression), reminiscence, therapy, ADL support, and caregiver-facing robot deployments. It is distinct from Category 1 (sensor- and platform-centered vital-sign or behavioral monitoring) and Category 2 (non-robotic daily-living technology), and from Category 3 (pure social or communication platforms) and Category 4 (non-embodied physical/cognitive interventions): if the physical robot is the central intervention or mediator, it belongs here; if the same function is performed by a software app or sensor-only system it belongs to those other categories. This category also includes studies of robot appearance, utterance style, acceptance, provider perceptions and deployment trials, while design-methodology, policy, or broad cultural/business analyses about robotics belong to Category 6 when the robot itself is not the primary evaluated artifact.”

## *6. General issues: design methodology, policy, education, culture, business, etc.*

Category 6 covers cross-cutting, non-technical research about how gerontechnology is designed, implemented, governed and sustained — including design and participatory methodologies, recruitment and evaluation methods, implementation science, policy and regulation, ethics and privacy, education and digital-literacy interventions, cultural and ageism analyses, stakeholder ecosystems, business models, and literature/theory reviews. It excludes studies whose primary focus is on specific devices, sensor systems, therapeutic or rehabilitative interventions, robots, or social/communication platforms (which belong in Categories 1–5); however, studies of those technologies are placed in Category 6 when their main contribution is about adoption, deployment, policy, training, or methodological lessons. Because overlap occurs (for example with social participation or daily-living support), Category 6 is best distinguished by its emphasis on context, processes, frameworks and systemic enablers or barriers rather than on technical features, clinical efficacy, or direct user outcomes.”